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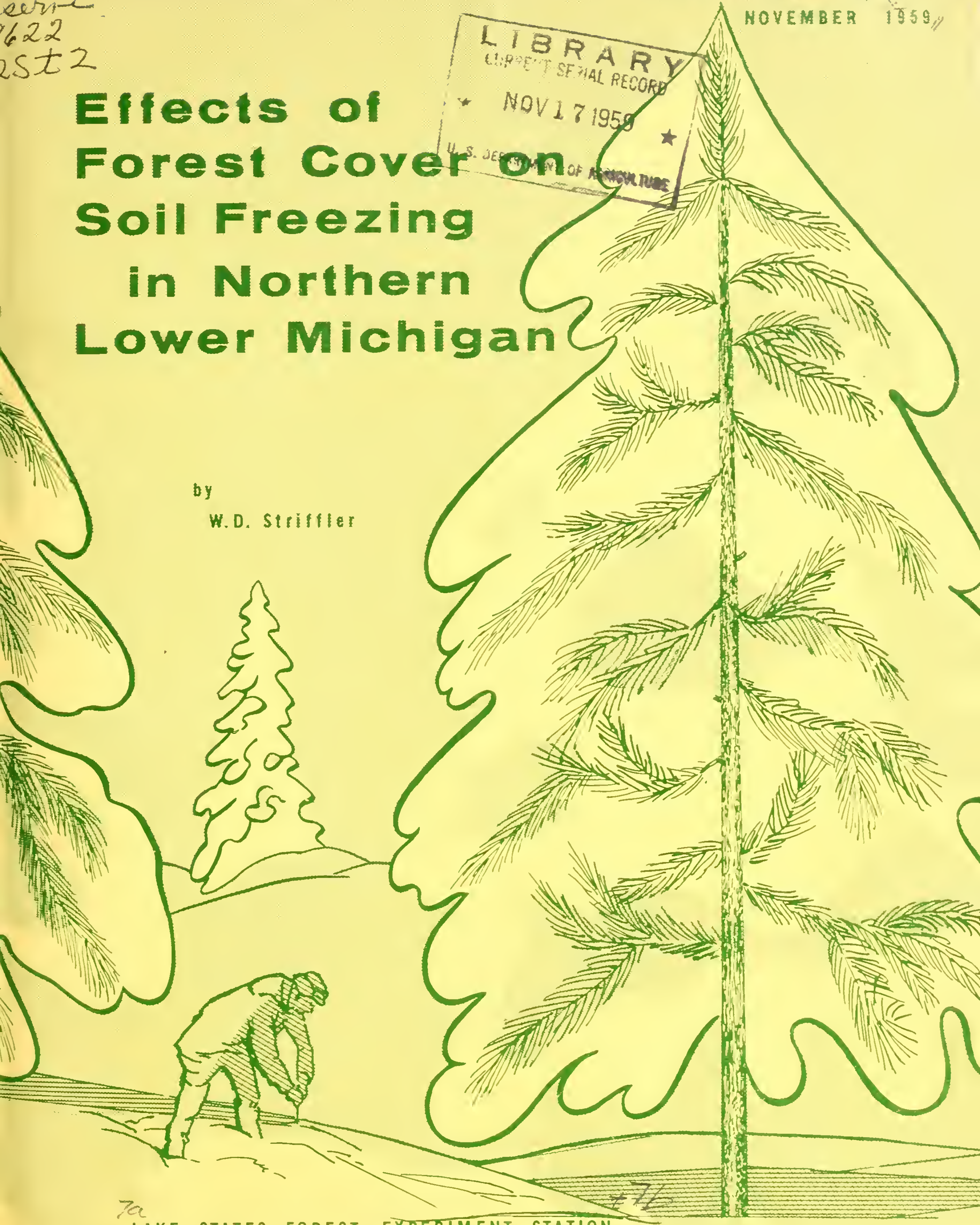
# Effects of Forest Cover on Soil Freezing in Northern Lower Michigan

by

W.D. Striffler



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and
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# Effects of Forest Cover on Soil Freezing

# in Northern Lower Michigan

by

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The presence and character of frost in the soil during the spring breakup period has hydrologic importance. One form, known as concrete frost, prevents the infiltration of melt water and rainfall, increases surface runoff, and may cause severe flooding and erosion (2, 8, 9, 11).[2] Other forms of frost, known as granular, stalactite, and honeycomb, are more permeable and less likely to cause excessive surface runoff (4, 7, 10).

Studies elsewhere have shown that the type of forest cover influences not only the character of frost formed but also the amount of snow accumulated and the rate of spring melt (1, 3, 12). To obtain similar information for northern Lower Michigan as part of an overall watershed management research program, soil freezing and snow accumulation were measured during the winter of 1957-58.

Four forest conditions were selected for study. These were: (1) Northern hardwoods, (2) mixed oak, (3) open red pine plantations with an average tree height of about 11 feet, and (4) closed red pine plantations with trees averaging 26 feet tall. These stand conditions are representative of major cover types in northern Lower Michigan.

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[1] Maintained at St. Paul 1, Minn., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Minnesota.

[2] Underlined numbers in parentheses refer to literature citations listed at the end of this report.

# Climate

Northern Lower Michigan has cold winters and mild summers. The first winter frost is usually in early October and the last one in early May. However, sustained freezing normally occurs only from December through March, when the monthly mean temperatures average below freezing (table 1). Mean annual precipitation for the study area is about 33 inches, with approximately 6.5 inches or 20 percent occurring as snow. This amounts to 80 inches of snow.

Table 1.--Departures from mean monthly temperatures in northwestern Lower Michigan, 1957-58

(Degrees Fahrenheit)

| Month | Mean monthly temperatures | | Departure from normal |
|---|---|---|---|
| | Period of record | Winter 1957-58 | |
| November | 36.0 | 36.8 | +0.8 |
| December | 25.4 | 27.9 | +2.5 |
| January | 21.7 | 22.8 | +1.1 |
| February | 20.8 | 17.7 | -3.2 |
| March | 28.1 | 31.3 | +3.2 |
| April | 41.7 | 43.4 | +1.7 |

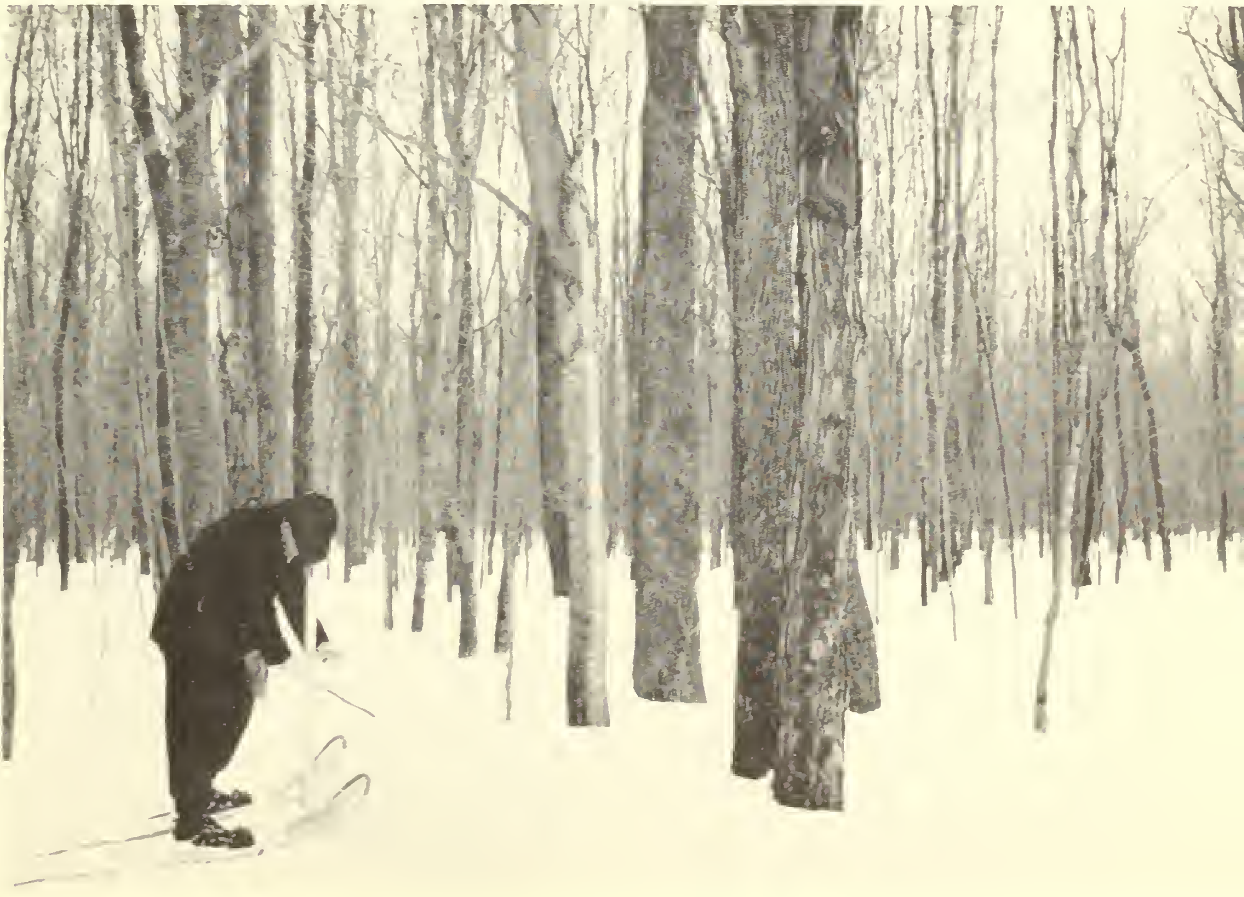
During the winter of 1957-58, snowfall in this same area totaled 49 inches (4.28 inches of water), which was approximately 40 percent below normal, and the temperature varied only a few degrees from normal (table 1). After the start of frost conditions, no important warming periods occurred to interrupt the accumulation of soil frost.

# Forest Conditions

The forest stands studied were on either loamy sand or sand soils. All sample areas had little or no slope.

Northern hardwood.--The species composition in the three northern hardwood plots was predominantly sugar maple (Acer saccharum), basswood (Tilia americana), beech (Fagus grandifolia), and white ash (Fraxinus americana). These stands contained an average of 895 trees per acre with diameters ranging from 1 to 20 inches. The basal area of the trees averaged 103 square feet per acre (fig. 1). The humus consisted of a layer of leaf litter over a well-developed mull profile. The mull humus has a mixture of organic matter and mineral soil.

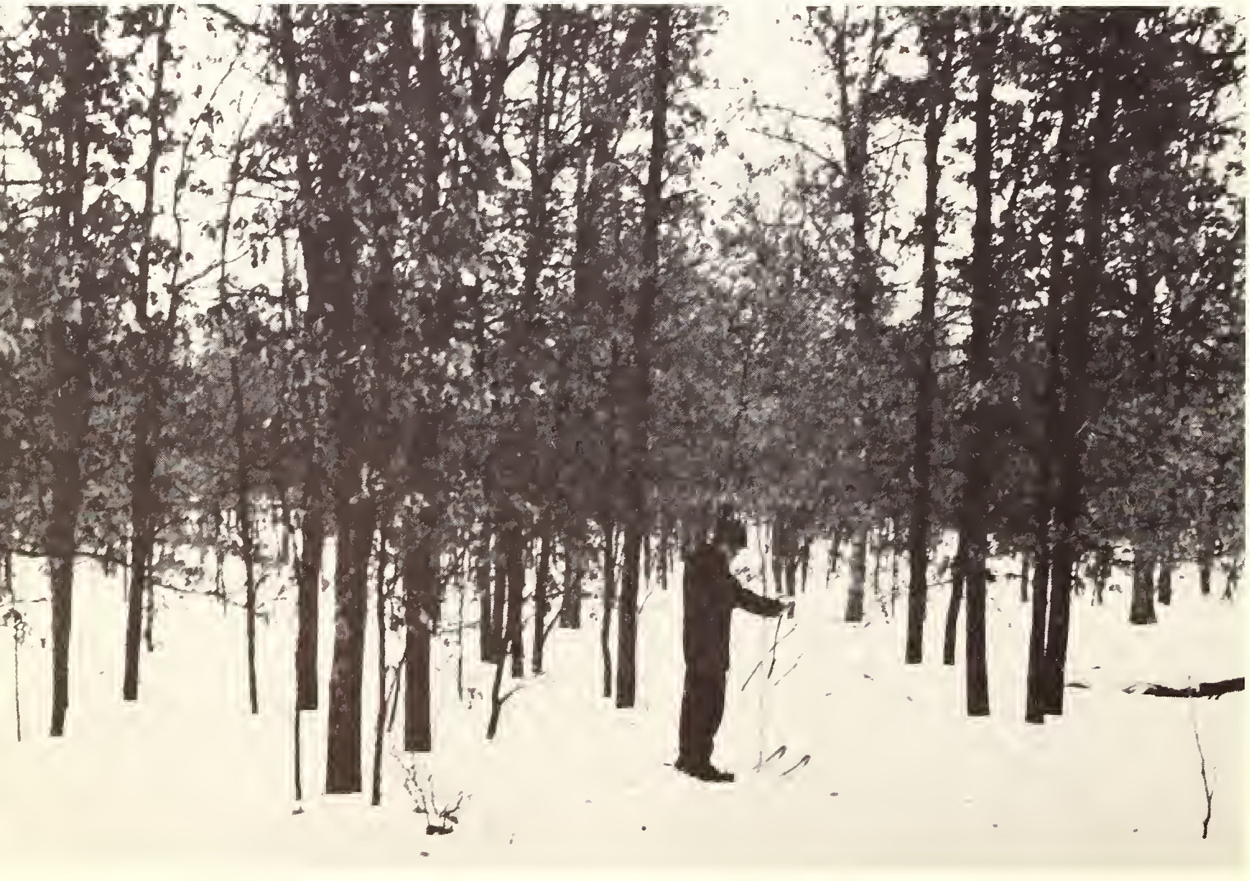
Figure 1.--Northern hardwood major species are sugar maple, ash, basswood, and beech. This type has a good snow catch, very little soil freezing, and a slightly delayed snowmelt period.



Oak.--The species composition in the three oak stands was predominantly northern pin oak (Quercus ellipsoidalis) (fig. 2). The stands contained 845 trees per acre with diameters ranging from 1 to 14 inches and an average basal area of 66 square feet. The humus under the oak consisted of a layer of oak leaf litter over a thin layer of raw humus which was only partially incorporated into the mineral soil. This humus form is classified as a duff mull.

Open red pine plantations.--The two open red pine plantations (Pinus resinosa) (fig. 3) were initially planted under an oak overstory. Seven years prior to this study the oak was cut or girdled to release the pine. Some of the larger girdled oak are still standing, leaving a snag effect. At the time of this study the pine averaged 780 trees per acre. Although the average age was 18 years, the pine were only 11 feet tall because of early suppression by the oak. The humus in these stands reflects the effects of both the original oak and the present pine cover. Where the oak leaf litter is still in evidence and undisturbed, the humus is a duff mull.

Figure 2.--Oak, almost entirely northern pin oak. This type, like northern hardwood, has good snow-catch abilities and very little soil freezing; snowmelt is only a little delayed.



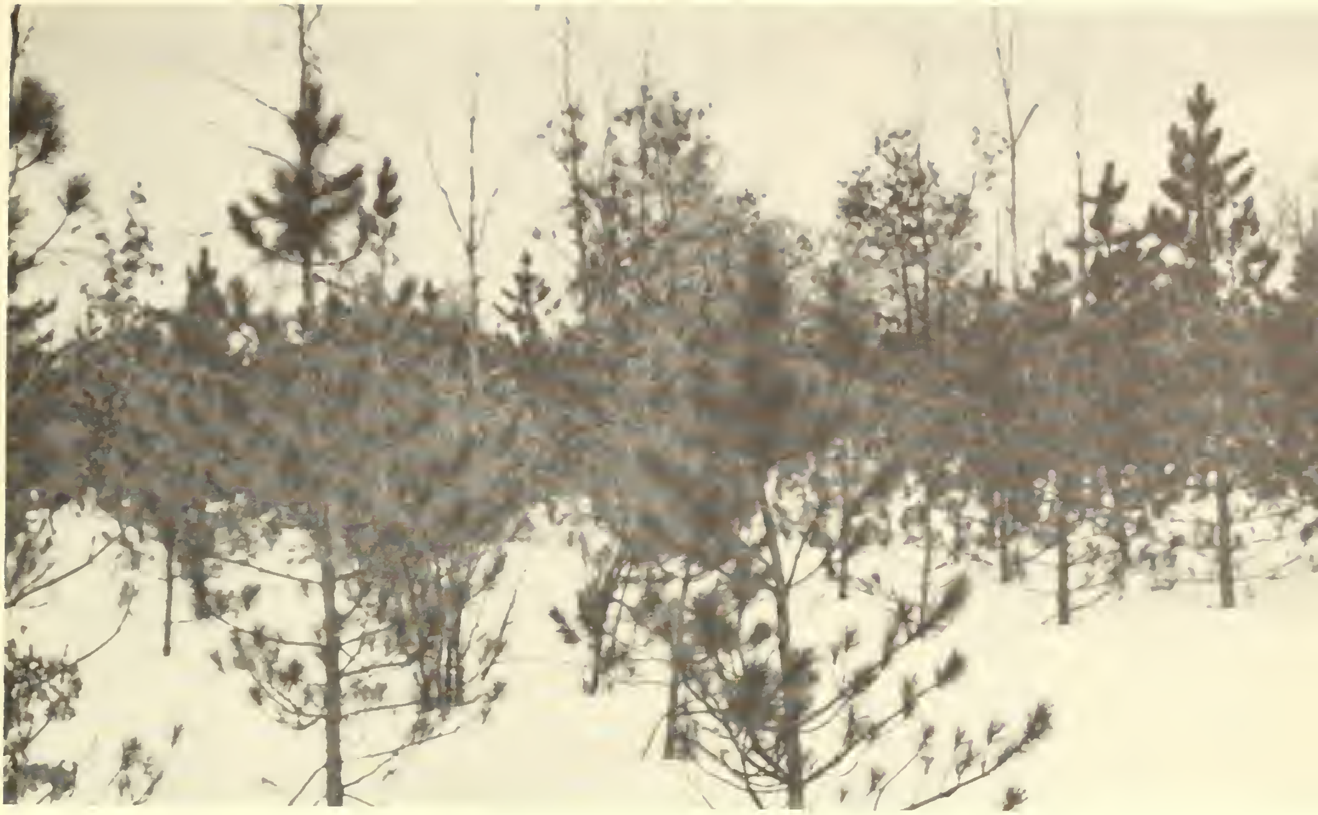


Figure 3.--Open red pine plantations after release, 23 years of age. Snow catch is the highest of the forest types sampled. Tendency to freeze is slight. Snowmelt varies, with snow remaining longest in the shaded areas and melting soon in the openings.

Where the pine have started to close and a needle litter predominates, a thin or imperfect mor may exist. In between these two extremes and predominating throughout the stand is a sand mull humus characterized by a thin litter layer of oak leaves, pine needles, and grass overlying a thin layer of incorporated organic matter.

Closed red pine plantations.--The three closed red pine plantations studied (fig. 4 on next page) were established in abandoned cultivated fields. At the time of study the trees averaged 18 years of age. There were 1,000 trees per acre averaging 26 feet in height and 100 square feet of basal area per acre. The crowns of these trees had been closed for at least 5 to 10 years. In these stands a weak mor or imperfect mor humus is beginning to develop. Since these stands were planted on old cultivated fields, a plow layer (Ap) is a predominant feature. The humus is characterized by a layer of pine needle litter lying directly over the plowed mineral soil horizon. Traces of raw unincorporated humus are occasionally

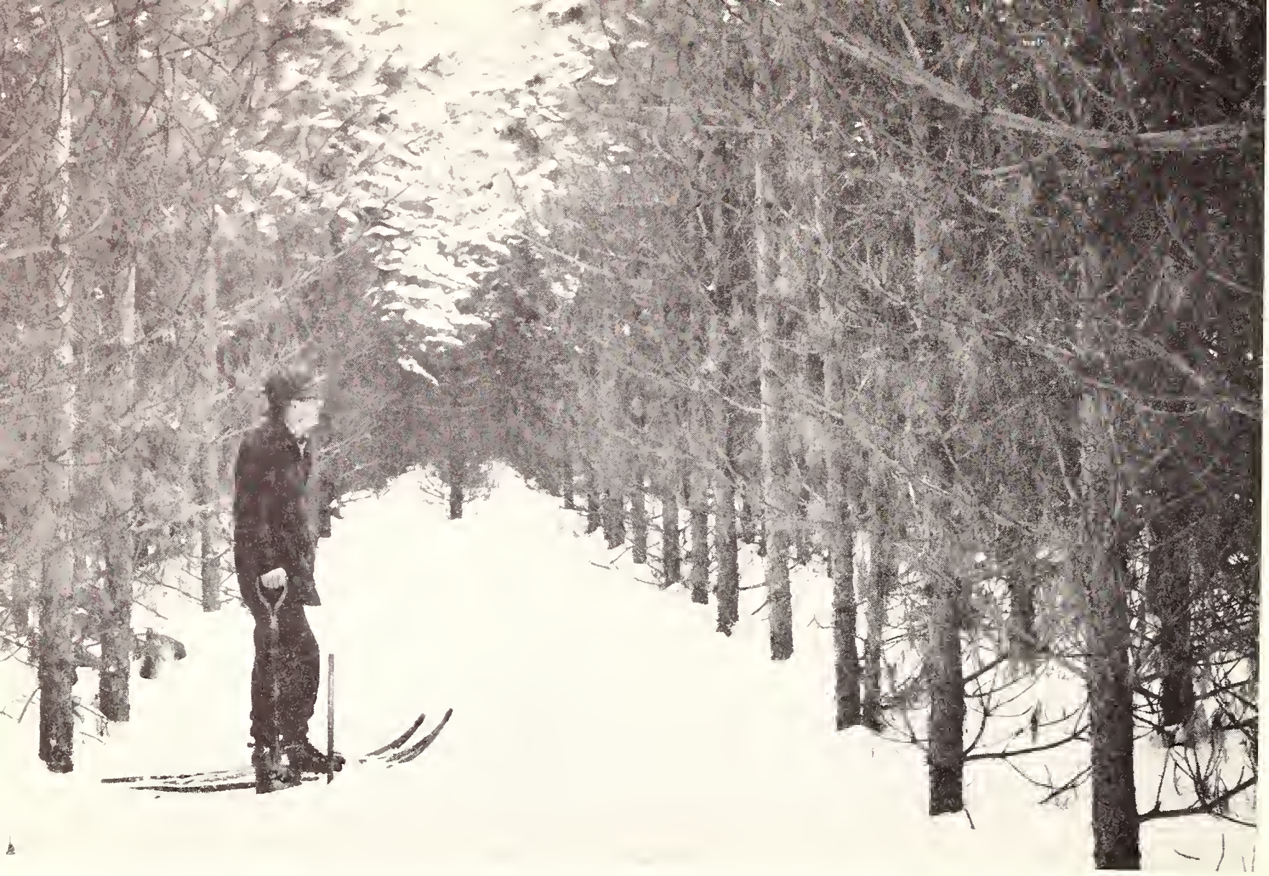


Figure 4.--Closed red pine plantation, about 20 years of age. Snow catch on the ground is poor because of high interception by the dense closed crowns. The soil is subject to deep freezing. Snowmelt is slowest of the forest cover types.

found. The plow layer (Ap) consists of a layer of mechanically incorporated organic and mineral soil. Organic contents are relatively low. Despite the presence of the plow layer, the humus is classified as a mor since organic matter from the existing stand does not appear to be mixing with the mineral soil.

## Study Methods

Study areas in each of the forest conditions consisted of ½-acre plots. On each plot the following periodic measurements were taken: (1) Frost type and depth, and (2) snow depth and water content. In addition to stand-density measurements, the type and depth of humus were determined.

The type and depth of soil freezing were observed at periodic intervals throughout the winter by making five hand excavations on each plot each sampling date. Frost depths were measured and types were determined by direct examination. Frost type was classified as granular, stalactite, honeycomb, or concrete (5, 8).

Snow-depth and water-equivalent measurements were taken at 15 points on each plot at the time of soil freezing observations. Measurements were taken with the Mt. Rose snow sampler and scales.

Humus types and depths were determined on each plot at five equal distant points. Humus types were classified according to the key proposed by Hoover and Lunt (6).

## Frost Occurrence

The three major frost types observed during the winter were granular, honeycomb, and concrete. The frequency with which each type occurred varied according to forest cover conditions (fig. 5).

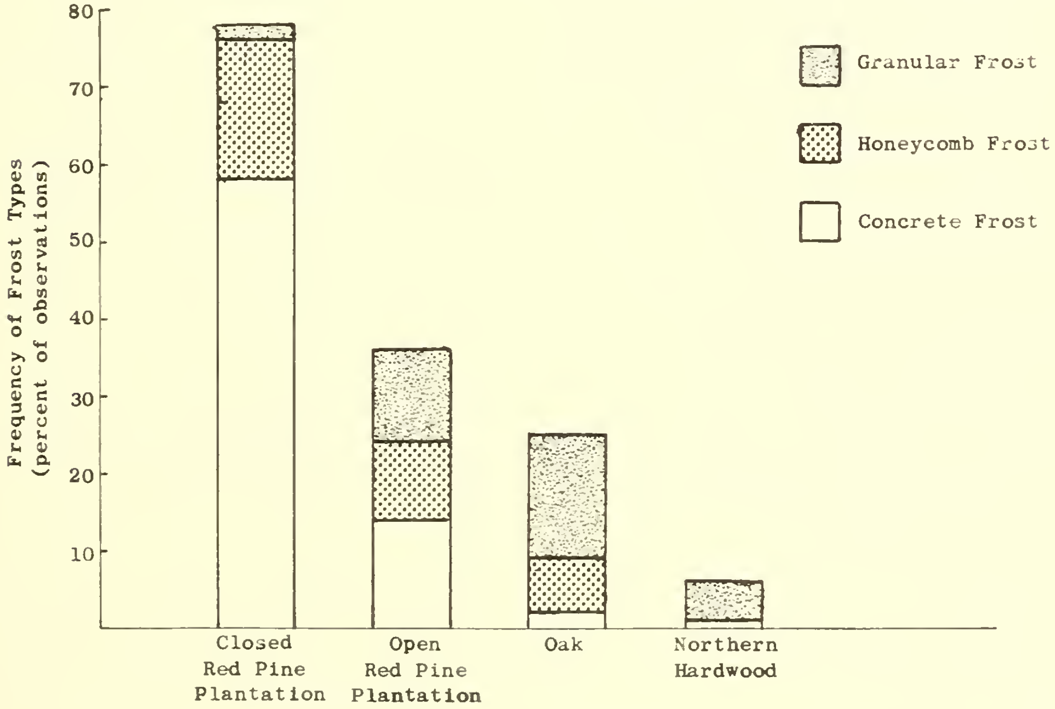


Figure 5.--Frequency of frost occurrence by forest type.

Frost was observed most frequently in the closed red pine plantations; here it occurred in 78 percent of all observations during the winter. Concrete frost was the predominant type, accounting for 58 percent of the observations. Furthermore, concrete frost appeared earlier and remained later in the closed pine plantations than in the other forest conditions (fig. 6).

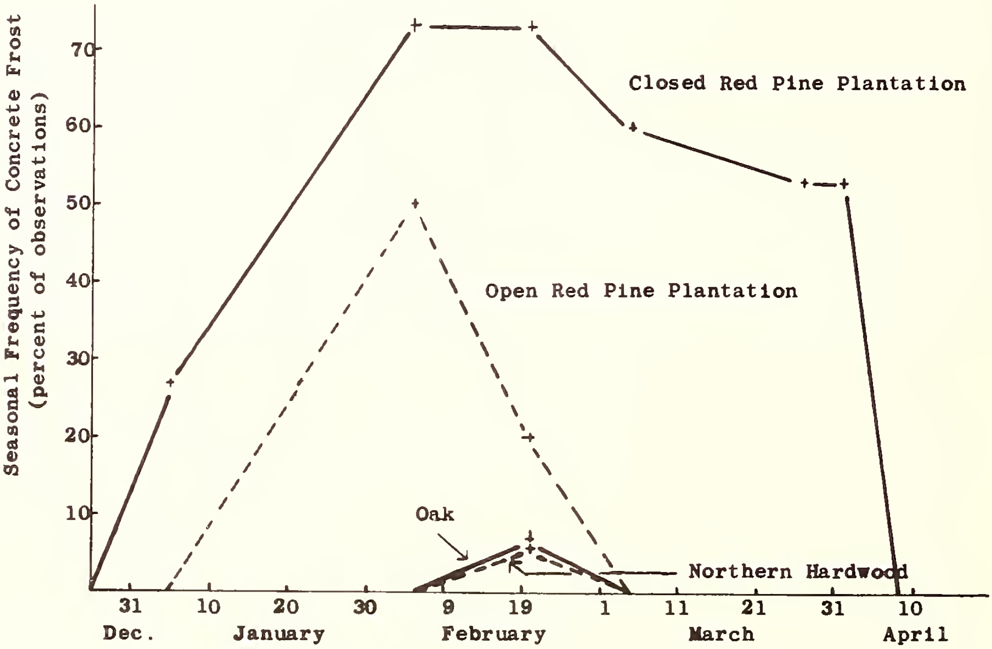


Figure 6.--Seasonal distribution of concrete frost.

The open red pine plantations had less frost; it occurred in 36 percent of all observations during the winter. Fourteen percent of the samples taken were concrete.

The oak and northern hardwoods had little frost during the winter. In the oak, 25 percent of all observations showed frost, and in the northern hardwoods, 6 percent. The frost was primarily granular or honeycomb with small patches of concrete frost occurring only during the coldest period of the winter (February 20 sampling date, fig. 6).

# Frost Depth

Depth of soil freezing also varied with forest condition (table 2). Granular and honeycomb frost forms were generally restricted to the surface 2 or 3 inches of soil (the $A_1$ horizon). Concrete frost was usually deeper but seldom went below the $B_1$ horizon.

Table 2.--Average and maximum depth of concrete frost by forest conditions

(In inches)

| Sampling date | Closed pine plantations |  | Open pine plantations |  | Oak |  | Northern hardwoods |  |
|---|---|---|---|---|---|---|---|---|
|  | Av. | Max. | Av. | Max. | Av. | Max. | Av. | Max. |
| Jan. 6 | 1.5 | 2.0 | 0 | - | 0 | - | 0 | - |
| Feb. 4 | 3.0 | 4.0 | 1.3 | 2.5 | 0 | - | 0 | - |
| Feb. 20 | 7.5 | 11.0 | 1.8 | 2.0 | 1.5 | 1.5 | 1.5 | 1.5 |
| March 5 | 4.7 | 7.0 | 0 | - | 0 | - | 0 | - |
| March 26 | 4.3 | 8.0 | 0 | - | 0 | - | 0 | - |
| April 6 | 0 | - | 0 | - | 0 | - | 0 | - |

Concrete frost depths were greatest in the closed red pine plantations where a maximum of 11 inches was measured. The open red pine plantings had less concrete frost with a maximum depth of 2.5 inches. The oak and northern hardwood stands had the least depth of concrete frost, 1.5 inches being the maximum.

## Effects of Snow

The effect of the forest upon snow accumulation and melt is one of the primary factors governing frost occurrence and depth. Snow depths vary with forest conditions.

In this study greatest snow depths occurred in the open red pine (fig. 7). The oak stands had the next greatest snow depths followed by the northern hardwood stands with their heavier stocking. Snow depths were least in the closed red pine plantation, probably because of the greater interception by the dense crown canopy. Conversely, more and deeper frost was observed in the closed red pine plantations than in other types.

Snowmelt also varied by cover condition. The snow disappeared first from the oak and northern hardwoods and last from the closed pine plantation. Here the dense crown shading and interception of solar radiation caused a marked reduction in the rate of snowmelt. While the comparatively light snowpack under the closed pine plantation lacked sufficient insulating effect to keep the soil from freezing, the same amount of snow was sufficient to prolong considerably the thawing of the frost accumulation.

## Effects of Humus

Another factor that appeared to be related to the occurrence and type of soil frost was the nature of the humus layer under each cover condition.

Under the northern hardwoods the hardwood leaf litter plus the well-developed mull profile seemed to have a good insulating effect. The crumb structure of the $A_1$ horizon did not usually permit the formation of concrete frost. Where frost did occur, it was primarily granular.

The oak leaf litter and duff mull profile found under the oak stand also had a good insulating effect. Frost under the oak was primarily granular and honeycomb, but there was also some concrete frost--more than in the northern hardwoods. Concrete frost can probably form more easily in the thin, single-grained $A_1$ horizon of the oak than in the deeper, crumb-structured $A_1$ of the northern hardwoods.

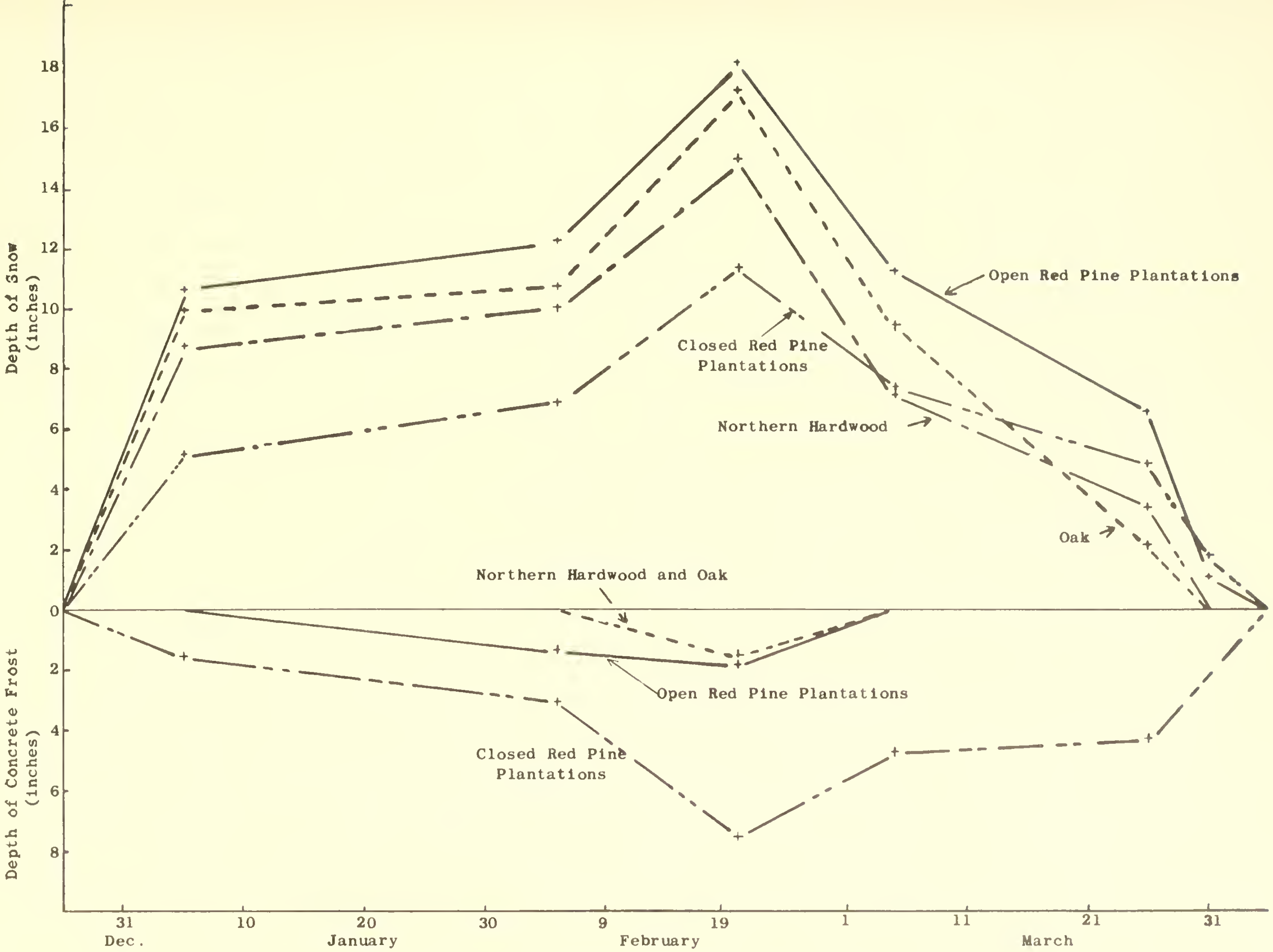


Figure 7.--Average depth of snow and depth of concrete frost by forest type.

Both litter and humus in the open red pine plantations are shallower than in the oak or northern hardwoods (table 3). Frost-forms in these stands are more likely to be concrete because of the thin litter, the shallow, single-grained $A_1$ horizon, and the mineral soil exposed when the pines were planted.

Table 3.--Humus types and depths by cover condition

(In inches)

| Cover type | Humus type | Litter depth | Humus depth[1] |
|---|---|---|---|
| Northern hardwood | Mull | 1.0 | 2.5 |
| Oak | Duff mull | 1.2 | 2.2 |
| Open pine plantation | Sand mull | .9 | 1.8 |
| Closed pine plantation | Imperfect mor | 1.3 | .2 |

1/ Humus includes the F and $A_1$ horizons in northern hardwoods and the open pine plantations; the F, H, and $A_1$ horizons in oak; and the F and H horizons in the closed pine plantations.

The closed red pine plantations had the deepest layer of litter, mostly pine needles. However, since the organic matter mixed very little with the mineral soil, the humus layer was very shallow. The prevalence of concrete frost in these plantations is due in part to the thin humus layer, the single-grained Ap mineral soil, and probably the past disturbance of this soil.

The amount of frost varied considerably within plots. For example, 3 or 4 inches of frost would be found in one part of a plot and none in other parts. Generally, these variations coincided with observable variations in snow depth or humus depth. Thus, although the independent effects of humus alone cannot be isolated, the results substantiate a general relationship between frost and humus.

## Discussion

The forests of northern Lower Michigan have an important influence upon frost occurrence, type, depth, and duration. This influence varies with forest cover condition. Although the role of the forest cover in frost formation is complex, it appears to be related to both snow and humus.

Those stands which discourage snow accumulation tend to have more and deeper frost. Thus the dense conifer stands, which intercept a considerable amount of snow, have deeper frost and a greater proportion of concrete frost. On the other hand, the oak and northern hardwood stands, which reduce snow accumulation only slightly, have relatively shallow frost of which only small amounts are of the concrete type.

Similarly, the duration of soil frost is affected by forest cover. The dense conifer stands shade the forest floor from the sun. This retards the melting of snow and the warming of the forest floor. As a result both snow and frost remain longer here than in the more open forest types.

Another part of the cover effect is the influence which the underlying organic layers have upon soil freezing. The forest type and condition determine the type and depth of the humus layer, which in turn affect soil freezing. For example, hardwood forests produce humus types which are incorporated into the mineral soil and are associated with the formation of granular and honeycomb frost. The pure conifer stands, however, produce thin organic layers which do not mix with the mineral soil. The single-grained mineral soil in the surface horizon under these stands is associated with the formation of concrete frost. It is interesting to note that of the cover types studied, those which permit deeper snow accumulation also produce humus types which are associated with less soil freezing.

## Summary

During the winter of 1957-58 a study was made in northern Lower Michigan to determine the effect of forest conditions upon soil freezing. Four important forest cover conditions were sampled: (1) Northern hardwood forest, (2) mixed oak forest, (3) open red pine plantations, and (4) closed red pine plantations. Measurements taken during the winter were (1) snow depth and water content, and

(2) depth and type of soil frost. In addition, the type and depth of humus were determined for each condition sampled. These measurements substantiate the following observations.

1. Red pine plantations with closed crowns accumulated less snow on the ground and froze to greater depths than any of the other forest conditions studied. Frost encountered in the closed red pine plantations was primarily of the impermeable concrete form. During the spring breakup both snow and frost remained longer in the closed pine plantation than in the other forest types.

2. Young open red pine plantations tend to accumulate slightly greater snow depths than all other cover types. They are not as subject to extensive soil freezing as are the closed pine plantations. Of the frost found in these plots less than half was of the concrete type. Snow remained in the open red pine nearly as long as in the closed plantations.

3. Very little frost was encountered under the oak. Of the frost that was found, granular and honeycomb forms were most common. The scrub oak stands accumulated slightly less snow than adjacent open pine plantings. The snow disappeared from under oak faster than from the other forested types studied.

4. Less frost was encountered under northern hardwoods than under the other cover types. Most of the frost was granular. The northern hardwood stands were intermediate in ability to accumulate snow.

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